National Aeronautics and Space Administration Goddard Earth Science Data Information and Services Center (GES DISC)

User Guide for Global Ammonia Retrievals from AIRS (Advanced InfraRed Sounder) Satellite Measurements

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Revision History

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1.0 Introduction

This document provides basic background information for the Global Ammonia Retrievals from AIRS Satellite Measurements products.

The mass concentration ammonia in the atmosphere, consists of products generated for the study of atmospheric ammonia. Atmospheric ammonia is an important component of the global nitrogen cycle. In the troposphere, ammonia reacts rapidly with acids such as sulfuric and nitric to form fine particulate matter. These ammonium containing aerosols affect Earth's radiative balance, both directly by scattering incoming radiation and indirectly as cloud condensation nuclei. Major sources of atmospheric ammonia involve agricultural activities including animal husbandry, especially concentrated animal feeding operations and fertilizer use. Major sinks of atmospheric ammonia involve dry deposition and wet removal by precipitation, as well as conversion to particulate ammonium by reaction with acids. Measurements of ambient NH_3 are sparse, but satellites provide a means to monitor atmospheric composition globally. Using the level2 retrievals from the AIRS/AMSU satellite, the ammonia algorithm provides monthly measurements of derived atmospheric NH_3 for September 2002 through August 2016. After August 2016, the channels on the AMSU instrument needed for this process failed. The datasets have the name of AIRSAC3MNH3 (monthly).

1.1 Dataset/Mission Instrument Description

The Atmospheric Infrared Sounder (AIRS) instrument suite is designed to measure the Earth's atmospheric water vapor and temperature profiles on a global scale. It is comprised of a space-based hyperspectral infrared instrument (AIRS) and a multichannel microwave instrument, the Advanced Microwave Sounding Unit (AMSU-A). The AIRS instrument suite is one of several instruments onboard the Earth Observing System (EOS) Aqua spacecraft launched May 4, 2002. The Aqua spacecraft orbit is polar sun-synchronous with a nominal altitude of 705 km and an orbital period of 98.8 minutes. The repeat cycle period is 233 orbits (16 days) with a ground track repeatability of +/- 20 km. The platform equatorial crossing local times are 1:30 in the morning (descending) and 1:30 in the afternoon (ascending).

The AIRS instrument is a grating spectrometer with 2378 separate spectral channels between 650 and 2670 cm^{-1} (15.3–3.8 μm) with a spectral resolving power on the order of 1200. Twelve channels of the AIRS radiances in the window regions (860–875, 928–932, and 965–967 cm^{-1}) are currently used to retrieve NH_3. These channels are carefully selected so that the retrievals are based on the NH_3 sensitivity, while the effects of the surface and overlapping gases are minimized. AIRS cloud clearing, described by Susskind et al. (2003), increases the data coverage significantly to nearly 50–70% of the total measurements, instead of the pure clear coverage of

approximately 10–15% at a 13.5 km single- view pixel size (Warner et al., 2013). AIRS NH_3 retrievals are based on the cloud-cleared radiances (CCRs) from AIRS L2 products. The averaging kernel (AK) peaks at about 918 hPa giving AIRS good sensitivity to lower tropospheric NH_3 because the planetary boundary layer generally extends above this altitude at the overpass local time of 1:30 p.m.

The algorithm used in this AIRS NH_3 study was based on a retrieval module developed for AIRS carbon monoxide (CO) products (Warner et al., 2010). This module was built upon and added to the current AIRS operational system or team algorithm (Susskind et al., 2003), but used a different minimization method. The NH_3 module uses AIRS Version 6 (V6) Level 2 (L2) profiles and errors from the previous retrieval steps (i.e., surface, clouds, water vapor, ozone, methane, CO) as input to the AIRS forward model – the stand-alone AIRS radiative transfer algorithm (SARTA) (Strow et al., 2003). The algorithm uses SARTA with the addition of NH_3 as a variable gas, which was carried out by Strow and co-workers, since the official AIRS forward model does not include NH_3 absorption as a variable. AIRS NH_3 retrievals use an OE method following the formulations given by Rodgers (2000), and also described by Pan et al. (1998). The OE retrieval output quantities not only include the NH_3 concentrations, but also provide the AKs, the error covariance, and the degrees of freedom for signal (DOFS), which benefit model verifications and data assimilation by using well-quantified errors.

The optimal estimation method requires an a priori mean profile and a corresponding error covariance matrix that represent the current knowledge of the geophysical property, i.e., NH_3, prior to the retrieval. Due to the high spatial variability and short lifetime of NH_3, a simple fixed a priori for all emission scenarios is not appropriate. Warner et al. (2016) developed a global mean, multi-year averaged (2003–2012), three-tier a priori from GEOS-Chem model (v9-02) simulations for high, moderate, and low pollution. They used GEOS-5 MERRA data sets from the NASA Global Modeling and Assimilation Office (Rienecker et al., 2011) to drive the meteorological fields in the GEOS-Chem simulations.

The same set of the three-tier a priori profiles is used globally and throughout the AIRS data record. Thus, any spatial and temporal NH_3 variations detected using this algorithm are from AIRS measurements. To select one of the three a priori profiles for each AIRS pixel, one examines the brightness temperature difference between a strong and a weak channel, divided by the measurement noise of the strong channel, defined as a “difference of brightness temperature index” (DBTI). This is similar to the method used by TES NH_3 and described by Shephard et al. (2011). The DBTIs vary with meteorological conditions and, most importantly, the thermal contrast at the surface. To take these effects into account, the relationship between the brightness temperature differences and TC under various meteorological conditions is simulated using SARTA. Warner et al. randomly picked 13,790 profiles from AIRS L2 products

over land from the months of January, April, July, and October in years 2003, 2008, and 2011, and then perturbed the NH_3 values spanning the three a priori mean profiles using the range of 0–100 ppbv multiplied by a random number for each atmospheric profile. The observed brightness temperatures were compared with the simulated values at a given TC to determine the level of a priori for the full retrievals. The higher DBTIs are correlated with higher DOFS, which represent higher surface thermal contrast (Deeter et al., 2007). The NH_3 retrieval quality assurance levels are determined based on the retrieval sensitivities under various meteorological and surface conditions using the AKs and the DOFS.

The algorithm also takes into account the performance of the retrievals against surface thermal contrasts from AIRS products. Additionally, the retrieval residuals and the number of iterations are examined to set proper quality assurance flags. The retrieval residuals in Kelvin (K) are defined by the square root of the mean variance of the observed brightness temperatures minus calculated. The NH_3 retrieval quality is affected by the meteorological properties, such as the vertical temperature and water vapor profiles, surface temperatures, and emissivity, which are used to model the atmosphere. The algorithm also adapts the error information provided by the AIRS CCR for the relevant channels, which includes meteorological quantities that are used in deriving the AIRS CCR. This error information is flagged by Q0, Q1, and Q2 with Q0 having the highest quality and Q2 being unusable. Although Warner developed AIRS NH_3 products for all available data sets, only the daytime and land cases are currently available. Additionally, only radiances with quality flag as Q0 are selected for the discussions in the following sections to ensure the best accuracy.

1.1.1 Dataset/Instrument

Information for the AIRS/AMSU L2 data products and instrument documentaion can be found on the GES DISC web site.

1.2 Algorithm Background

Additional information about the Ammonia retrieval algorithm can be found in the ATBD.

1.3 Data Disclaimer

The current global data products are for daytime over land. The data products are released to the public as is.

1.3.1 Data User Acknowledgment

Warner, J. X., Z. Wei, L. L. Strow, R. R. Dickerson, and J. B. Nowak (2016), The global tropospheric ammonia distribution as seen in the 13-year AIRS measurement record, Atmos. Chem. Phys., 16, 5467-5479, https://doi.org/10.5194/acp-16-5467-2016

1.3.2 Contact

Information

Inquiries regarding the data product can be directed to Juying X. Warner juying@atmos.umd.edu.

1.4 What's New?

Warner et al. (2016; 2017) used V2 of this algorithm and the current data have been updated to V3. The main difference between versions is that the correlation between a layer above 500 hPa and a layer below is removed. This is because there is very little ammonia information above 500 hPa level in the current algorithm. We also updated AIRS L2 profiles noises, using the same V6 L2 profiles.

2.0 Data Organization

The data consists of monthly 1 degree latitude by 1 degree longitude globally gridded level-3 products. The data consists of daytime land only values.

2.1 File Naming Convention

The AIRSAC3MNH3 monthly files follow the following naming convention:

AIRS_NH3_VMR.*mmm.yyyy***.*V3.nc***

Where:
mmm = 3 character abbreviation for the month
yyyy = 4 digit year number [2002 to 2016]

Filename example: AIRS_NH3_VMR_jul.2006.V3.nc

3.0 README Guide

The Global Ammonia Retrievals from AIRS (Advanced InfraRed Sounder) Satellite Measurements README guide provides information and instructions related to reading the data products.

4.0 Data Services

The data is distributed by the NASA Goddard Earth Sciences Data and information Services Center.

If you need assistance or wish to report a problem:
Email: gsfc-dl-help-disc@mail.nasa.gov
Voice: 301-614-5224
Fax: 301-614-5268
Address:
Goddard Earth Sciences Data and Information Services Center NASA Goddard Space Flight Center Code 610.2 Greenbelt, MD 20771 USA

4.1 How To Articles

The GES DISC web site contains many informatiative articles under the "How To Section", "FAQ" (frequently asked questions), "News", "Glossary", and "Help" . A sample of these articles includes:

Earthdata Login for Data Access

How to Download Data Files from HTTPS Service with wget

How to Obtain Data in NetCDF Format via OpeNDAP

Quick View Data with Panoply

How to Read Data in NetCDF Format with R

How to Read Data in HDF-5 or netCDF Format with GrADS

How to read and plot NetCDF MERRA-2 data in Python

How to Subset Level-2 Data

How to use the Level 3 and 4 Subsetter and Regridder

5.0 More Information

Additional information abou the AIRS/AMSU L2 data products and documentaion can be found on the GES DISC web site.

6.0 Acknowledgments

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